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SONAR TRANSDUCER RELIABILITY IMPROVEMENT PROGRAM (STRIP) FY80.(U)
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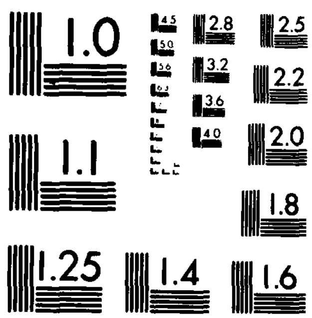

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Progress accomplished during the third quarter of FY80 in the Sonar Transducer Reliability Improvement Program (STRIP) is reported. Each of the six major task areas is discussed in detail. Several goals, during completed, this quarter include: the current phase of research on TCP for use as a transducer fill-fluid; investigation of the strength of shielded and unshielded MIL-C-915/8E cable types; and the first draft of the handbook for connector and cable harness design was partially completed. Progress in other task areas included:

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ITEM 20:

CUALT performed on two DT-605 hydrophones which simulated 3 years of life service; (the CUALT procedures and methods applied to sonar transducers were documented by an NOSC report); and three TR-155F transducers were retrofitted with glass-loaded polyester pressure release mechanisms and passed all acoustic extraneous noise tests.

CONTENTS

Sonar Transducer Reliability Improvement Program

NRL Problem 0584

FY80 Third Quarter Progress Report

1. INTRODUCTION

1.1. PROGRAM OVERVIEW

The general objective of this program is to perform relevant engineering development which addresses the operational requirements for fleet transducers for active sonar, passive sonar, surveillance, counter-measures and deception devices, navigation, and acoustic communications. The approach is to develop, test, and evaluate improved transducer design, materials, components, and piece parts that will meet specified requirements in the operational environment during the entire useful life of the transducer. Standards will be prepared to ensure that results obtained during preliminary testing will be obtained consistently in production. This program should result in improved performance and reliability and reduced costs through better utilization and a more comprehensive characterization of materials and design data. The program goals are as follows:

- Reduction in transducer replacement costs

  Goal - less than 9% of population replaced each year with no automatic replacements at overhaul.
  Threshold - less than 18% of population replaced each year.

- Improvement in transducer reliability

  Goal - less than 1% of population failures each year.
  Threshold - less than 3% of population failures each year.

- Improvement in transducer receiving sensitivity

  Goal - less than ±1 dB variation from the specified value over operational frequency band.
  Threshold - less than ±2 dB variation from the specified value over operational frequency band.

The Sonar Transducer Reliability Improvement Program (STRIP) is a part of Program Element 64503N. Major task areas with specific objectives to achieve the program goals have been described in the Program Plan and include:

- Task Area A - Encapsulation Methods
- Task Area B - High Voltage Engineering
- Task Area C - Cables and Connectors

- Task Area D - Transducer Material Standards
- Task Area E - Environmental Test Methods
- Task Area F - Transducer Tests and Evaluation

The FY80 Program Plan for STRIP has been funded at the $495K level. The specific tasks and their Principal Investigators for FY80 are listed below:

	TASK	PRINCIPAL INVESTIGATOR	
A-1	Fluids and Specifications	NRL	C.M. Thompson
B-1	Corona Abatement	NRL	L.P. Browder
C-1	Handbook for Harness Design	GD/EB	R.F. Haworth
C-2	Standard for O-Ring Installation	APL/University of Washington	C.J. Sandwith
C-3	Cable and Connectors	TRI	D.E. Glowe
D-1	Alternative Materials - Plastics	NWSC	D.E. Moore
D-2	Pressure Release Materials	NUSC	C.L. LeBlanc
E-1	CUALT	NOSC	J. Wong
E-2	ALT Verification	NWSC	D.E. Moore
F-1	Failure Modes due to Water	TRI	D. Barrett
F-2	Shock Hardened Pressure Release	Westinghouse	C.R. Wilson
F-3	Reliability & Life Prediction Specification	TRI	R.L. Smith
F-4	Engineering Documentation	NRL	R.W. Timme

1.2. SUMMARY OF PROGRESS

During the third quarter of FY80, efforts in the various tasks of STRIP have resulted in progress toward the program goals as summarized below:

- The current phase of research on tricresyl phosphate (TCP) for use as a transducer fill-fluid has been completed. See Section 2.3.1.

- The first draft of the handbook for connector and cable harness design has been partially completed. See Section 4.3 for the table of contents.

- The investigation of the strength of shielded and unshielded MIL-C-915/8E cable types has been completed. See Section 6.3.

- CUALT has been performed on two DT-605 hydrophones to simulate three years of life service. The hydrophones are still completely within specification and no design

problems have been found, testing continues. CUALT procedures and methods applied to sonar transducers have been documented by an NOSC report. See Section 9.3.

- Three TR-155F transducers have been retrofitted with glass-loaded polyester pressure release mechanisms and have passed all acoustic and extraneous noise tests. See Section 12.3.

1.3. PLANS

The Program Plan for the FY81 STRIP has been submitted to, and is currently being reviewed by, NAVSEA Code 63XT.

1.4. REPORT ORGANIZATION

The remaining sections of this quarterly report will discuss the objectives, progress, and plans for the specific tasks included in the STRIP.

2. TASK A-1 - TRANSDUCER FLUIDS AND SPECIFICATIONS

C.M. Thompson - NRL-USRD

2.1. BACKGROUND

A material to be used for filling a sonar transducer must meet a wide variety of specifications. The requirements imposed by the electrical nature of the device include high resistivity, high dielectric constant, as well as resistance to corona and arc discharges. The water environment of the transducer necessitates low water solubility and other attractive solution properties. In addition, the fluid must maintain its electrical and other properties in the presence of any water which permeates the covering. The acoustic requirements are a close acoustic impedance match with seawater and resistance to cavitation at high-drive levels. Other obvious properties include compatibility with other components, stability to degradation, and suitable surface tension and viscosity.

With such a wide variety of requirements, it is not surprising that compromises have to be made. The most commonly used fluid for many years has been castor oil. This use is in spite of its high viscosity. Each of the fluids proposed, so far, as a replacement has serious drawbacks. Silicone oils tend to creep onto and wet all of the surfaces of the transducer. This greatly complicates bonding the components together. Polyalkylene glycol (PAG) has the disadvantages of a high water solubility and low electrical resistivity. The various hydrocarbon liquids have too low an acoustic impedance and are frequently incompatible with the various plastics and rubbers in the transducer. Further research is necessary to find and qualify fill-fluids which represent the best match to all the requirements imposed upon it.

2.2. OBJECTIVES

The objectives of this task are:

- To find plausible new transducer fill-fluids which combine the best properties. Candidates include: hydrophobic-polyethers, sterically protected esters, chlorine - or fluorine - containing hydrocarbons, and possibly aromatic hydrocarbons.
- To apply the criteria developed during the PAG and castor oil testing to the most promising candidate fluids.

2.3. PROGRESS

2.3.1. Tricresyl phosphate (TCP) was discussed in the STRIP FY80 First Quarter Progress Report [1] as a sonar transducer fill-fluid. This material is a widely available aromatic phosphate ester with many properties which make it seem a likely candidate. During this quarter the investigation of TCP's potential for long-term corrosion due to hydrolysis was completed. A series of potentiometric titrations of water-TCP mixtures held at a range of temperatures for periods up to four weeks revealed no buildup of

acidity. In the test of metals [2] exposed to TCP-water, there was no pitting corrosion on any samples and only mild steel showed evidence of any surface attack. Despite the fact that the activation energy for the hydrolysis is unknown, all of the above tests represent very long sea exposure times. It is thus concluded that TCP poses no threat of metal corrosion in transducer use.

An accelerated test of some other materials has recently been completed. Epon VI, a commonly used epoxy adhesive, was shown to be affected only slightly by TCP. "Lexan" polycarbonate showed poor compatibility with TCP. In LC-800, a cork-silicone decoupling material, TCP caused a moderate increase in weight and presumably a moderate degradation in acoustic performance.

2.3.2. A second series of compatibility tests have been completed for Isopar M, a widely used towed-array fill-fluid. Epon VI showed few signs of degradation. Syntactic foam also showed little change on being exposed to Isopar M. "Tygon" brand PVC tubing which has been proposed as a hosewall material for towed arrays, showed poor compatibility with Isopar M. The Tygon both increased in weight and became much harder upon exposure to Isopar M. Of the cork-rubber decoupling materials tested, DC-100 (cork-Neoprene) and LC-800 (cork-silicon) changed severely while NC-775 (cork-nitrile rubber) showed very little change. As with other fluid and cork-rubber combinations, these compatibilities parallel the compatibility of the Isopar M with the rubber alone.

2.4. PLANS

- Continue work on water permeation into sonar transducers and the effect this has on operation and lifetime (cooperative between Tasks A-1 and F-1).
- Publish report containing detailed physical, chemical, and acoustic properties of a wide variety of transducer and towed-array fluids.

3. TASK B-1 - CORONA ABATEMENT

L.P. Browder - NRL-USRD

3.1. BACKGROUND

A significant percentage of transducer failures is due to voltage breakdown of insulating materials developing from corona erosion mechanisms. It is not practical to test the end item (transducer) to quantify the effects of corona erosion on transducer reliability and lifetime. Corona must be studied as a failure mechanism at the component or piece-part level to quantify the protection requirements and establish reliability factors. Transducer reliability may then be achieved by control of design parameters and construction processes.

3.2. OBJECTIVES

The objectives of this task for FY80 are:

- A complete investigation of the lifetime function of PZT ceramic exposed to various levels of corona discharges in different gases and gas impurity mixtures.
- A formulation of the elementary transducer reliability function based on electrical breakdown considerations.

3.3. PROGRESS

3.3.1. Tests were conducted to evaluate the effect of temperature on the PZT ceramic lifetime function and to observe any significant changes of the corona discharges or the corona inception level caused by temperature. The PZT ceramic lifetime function test was described in the STRIP FY79 Fourth Quarter Progress Report [3]. A temperature of 60°C was used in these measurements to be representative of the sonar transducer operating condition. The temperature was developed in the high-voltage test vessel by a small heating element powered by a temperature controller (YSI model 74) with a series 400 thermistor probe.

Figure 3.1 shows the data and average curves obtained from these tests at 60°C using dry air and sulfur hexafluoride (SF_6). They are compared to the curves for the gases obtained at 25°C [3]. For most of the test specimens, corona discharges were greater and more numerous at 60°C than for the comparable condition at 25°C. Temperature had about the same effect on the lifetime function in both gases, failure occurred more rapidly in the intermediate area [3] of the curve.

Four specimens were tested at most of the drive voltage levels so that an average failure time could be computed. Analysis of this data also reveals some aspects of reliability relative to electrical breakdown. Most important, perhaps, is the trend of the failure distribution at higher voltage drive levels that indicates a wearout type failure. In the lower

voltage area, the distribution is characteristic of the random or constant failure rate typical of the middle part of the failure rate bathtub curve. This is a good indication that electrical failure of sonar transducers have a constant failure rate that increases exponentially with the voltage drive level. A further test of the effect was made involving nine specimens in dry air at 25°C when driven at 6.5 kV, the results showed the same random distribution. The mean time before failure (MTBF), however, was 3.4 hours as compared to about one hour on the dry air curve in Fig. 3.1. This is an indication that the dry air curve of Fig. 3.1 (25°C) could be improved.

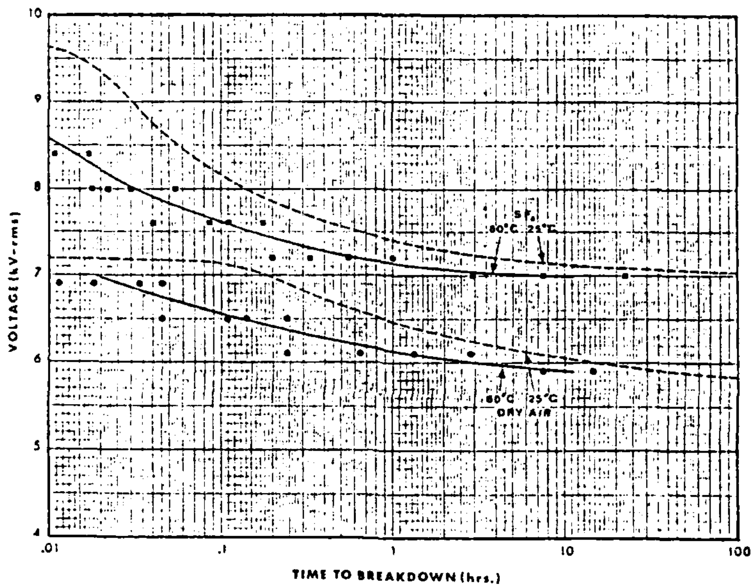

Fig. 3.1. - Voltage Lifetime Functions for 0.635-cm Thickness PZT Ceramic at 25°C and 60°C in Dry Air and SF_6 Gases.

3.3.2. Continuing the investigation of the parasitic current phenomena on the PZT ceramic surface [3] indicates that this is the primary failure mechanism when insulating gas is SF_6 and probably also when C_2F_6 and C_3F_8 are used. When the insulating gas is air, however, this mechanism is active but voltage breakdown appears to be initiated by a high-level corona burst. In fact, there appears to be several different ways that voltage breakdown may occur on PZT ceramic.

3.3.3. Methods are being investigated to study voltage breakdown of PZT ceramic at frequencies greater than 60 Hz. NRL-USRD has a power amplifier that can provide voltage drive to 4.5 kV. This is adequate to test 0.635-cm thickness PZT ceramic at a voltage stress of 708 kV/m (18 V/mil). The intent is to test the specimens at a frequency of approximately 5 kHz. It may be desirable to test at a higher voltage than this, therefore, a 10-kV transformer is being obtained. There has been no progress in finding a corona detector that will operate at these frequencies.

3.4. PLANS

- Formulate the elementary transducer reliability function based on electrical breakdown considerations and write an interim report.
- Set up equipment for high-frequency high-voltage testing of PZT ceramic and evaluate the voltage endurance function in dry air.

4. TASK C-1 - HANDBOOK FOR CONNECTOR AND CABLE HARNESS DESIGN

G.D. Hugus - NRL-USRD
R.F. Haworth - Electric Boat Division
General Dynamics Corporation

4.1. BACKGROUND

The selection of pressure-proof connectors and cable harnesses for hydrophones and transducers is a critical part of Navy shipboard sonar system design. Yet, the design of these components for use in this environment is not covered in any one reference publication. Information on this subject is contained in a multitude of military and industry specifications, standards, and publications. The result is that engineers and designers often duplicate work and may overlook relevant information that they need.

4.2. OBJECTIVE

The objective of this task is the preparation of a design handbook covering the technology of pressure-proof underwater connectors and cable harnesses for hydrophones and transducers. The emphasis will be on the application of these components for use in naval surface ships and submarines.

4.3. PROGRESS

Work to fulfill this objective began on 31 January 1980 under contract N61339-80-C-0021 by the Electric Boat Division of the General Dynamics Corporation. The drafts of the following sections of the handbook have been completed and the table of contents are listed for each.

- SECTION 1 - RESPONSIBLE NAVSEA TECHNICAL AGENCIES

  Sonar Systems
  Pressure-Proof Electrical Connectors, Cable Harnesses and Hull Penetrators
  Outboard Electrical Cables

- SECTION 2 - NAVSEA-APPROVED PRESSURE-PROOF ELECTRICAL CONNECTORS

  General
  MIL-C-24231 Connectors
  Surface Ship Connectors
  MIL-C-24217 Connectors
  MIL-C-22539 Connectors
  TRIDENT Submarine Connectors
  Miniature Pressure-Proof Connectors
  Dolphin Submarine Connectors
  Field Assembly Connectors
  NR-1 Connectors
  DSRV Connectors
  DSV Oil-Filled Connectors
  Sea Cliff - Turtle Connectors

RAPLOC Wide Aperture Array Connectors
D.G. O'Brien, Inc., 110 Series Coaxial Connectors
Deep Ocean Technology Program 20,000-ft Operating Depth Connectors
Pressure-Proof Cable Glands
Cable Stuffing Tubes
MIL-C-22249 Connectors
Naval Laboratory Connectors
Underwater Make and Break Connectors

- SECTION 3 - NAVSEA-APPROVED OUTBOARD CABLES

  General
  MIL-C-915 Cables
  - DSS Type Cables
  - 2SWF Type Cables
  - 1 SWF-2 Cable
  - MFW Type Cables
  - S2S Cables

  MIL-C-17 Coaxial Type Cables
  TRIDENT Submarine Cables
  DSV-3 and DSV-4 Cables
  Dolphin Cables
  NR-1 Cables
  DSRV Cables
  DSV-4 (20,000-ft) Cables
  Sonar System Manufacturer Outboard Cables

- SECTION 4 - NAVSEA-APPROVED CABLE HARNESSES

  General
  MIL-C-24231 Connector Cable Harnesses
  MIL-C-24217 Connector Cable Harnesses
  MIL-C-22539 Connector Cable Harnesses
  Surface Ship Connector Cable Harnesses
  TRIDENT Submarine Cable Harnesses
  Dolphin Submarine Cable Harnesses
  NR-1 Cable Harnesses
  Sea Cliff - Turtle DSV Cable Harnesses
  DSRV Cable Harnesses
  DSV-20,000 Cable Harnesses
  RAPLOC Wide Aperture Array Cable Harnesses
  Sonar System Component Cable Glands
  AN/BRA-8C Cable Harness
  AN/BQR-21 Cable Harness
  AN/BQR-19 Cable Harness
  AN/SQS-26 Cable Harness
  AN/SQS-38 Cable Harness
  AN/SQS-35 Cable Harness

- SECTION 5 - NAVSEA-APPROVED SUBMARINE HULL PENETRATORS

    General
    Electrical Hull Penetrator Design
    MIL-C-24231 Submarine Hull Penetrators
    Submarine Sonar Sphere Penetrators
    TRIDENT Submarine Hull Penetrators
    Surface Ship Cable Stuffing Tube Penetrator
    Dolphin Submarine Hull Penetrator
    NR-1 Hull Penetrator
    DSRV Hull Penetrator
    Sea Cliff - Turtle Hull Penetrator
    DSV Hull Penetrator
    RAPLOC Wide Aperture Array Hull Penetrator
    Deep Ocean Technology Program 20,000-ft Operating Depth Hull Penetrator
    Multi-Cable Stuffing Tube Hull Penetrator
    MIL-C-22249 Missile Tube Penetrators

- SECTION 6 - PRESSURE-PROOF ELECTRICAL CONNECTOR DESIGN

    General
    Electrical Connector Types
        Metal Shell Connectors
        Molded Plastic Connectors
        Molded Elastomer Connectors
    Connector Design Parameters
        Connector Configuration
        Connector Types and Sizes
        Plug Design
        Receptacle Design
        Material Selection
        Pin and Socket Contact Design
        Connection-Conductor to Socket Contact
        Fastening-Plug to Receptacle
        Sealing-Plug to Receptacle
        Insulation and Seal-Pin Contact
        Insulation and Seal-Socket Contact
        Seal-Cable to Plug
        Cable Strain Relief
        Connector Accessories
            Pressure-Proof Covers
            Protective Covers

- SECTION 7 - PRESSURE-PROOF CONNECTOR RECEPTACLE ATTACHMENT METHODS

    General
    Welded Receptacles
    Threaded or Bolted Receptacles
    Elastomeric Bonded Receptacles

- SECTION 12 - CABLE HARNESS TEST REQUIREMENTS

    General
    Qualification Tests
    Quality Assurance Tests
    Test Methods and Performance Requirements
        Examination of Product
        Continuity
        Insulation Resistance
        Dielectric Withstanding Voltage
        Cable Flexing
        Hydrostatic Pressure - Static
        Thermal Shock
        Vibration
        Shock
        Accelerated Aging
        Hydrostatic Pressure - Cycling
        Bond-Boot to Connector (Destructive)
        Post Test Examination of Product

- APPENDIX A - GLOSSARY

    For a better understanding of the terminology used in this handbook, the following glossary is presented. Rather than compiling one list of terms, the nomenclature is separated into five categories:

        Connector Plug
        Connector Receptacle
        Hull Penetrator
        Cable
        Cable Assembly

- APPENDIX B

    Pertinent Military Test Specifications
    Maximum Conductor Current Rating
    Fractions of an Inch with Metric Equivalent
    Unit Prefixes
    Nomenclature of Frequency Bands
    Deep Submergence Tables
    Relation Between Various Pressure Units

4.4. PLANS

Work will be devoted to the first draft of the handbook during the fourth quarter of FY80. The first quarter of FY81 will be spent on completion and review of the handbook which is to be published during the second quarter of FY81.

5. TASK C-2 - STANDARD FOR O-RING INSTALLATION

Dr. C.J. Sandwith - APL University of Washington
G.P. Hugus - NRL-USRD

5.1. BACKGROUND

The reliability of sonar transducer arrays can be significantly improved by the adoption of standard procedures for the installation and assembly of O-ring seals. The problem is that no such standard procedure exists. Presently, the installation procedures are determined by the installer and the materials available at the time of installation.

The results of analyzing failures of O-ring seals in connectors used in underwater applications over decades show that roughly eight out of thirteen O-ring failures have resulted from improper installation and assembly or improper quality control and inspection procedures at the time of assembly. Stated another way, the results showed that even though O-ring seal design may be perfected by the proper O-ring type selection (piston, face, or crush) by the maximum crush section thickness, by selecting the proper O-ring size and material, and by using two O-rings in series (double O-rings) a substantial number of the O-ring seal failures will occur due to improper installation and inspection procedures.

5.2. OBJECTIVES

The objective is to compose, critique (by authorities), edit and present in final form a standard procedure for the installation of O-ring seals in electrical connectors and undersea static applications. The standard will be composed in the form of similar military standards. Once it is approved by NRL and NAVSEA authoritites it will be submitted for approval as a military standard.

5.3. PROGRESS

Work to fulfill this objective is being performed under contract N00024-78-C-6018 by the Applied Physics Laboratory of the University of Washington. The approach to developing this procedure is to use all known proven techniques and procedures of users (military and commercial) and suppliers to develop a unified best procedure. The approach is to collect from the literature, users, and suppliers, all of the data and recommendations concerning each phase of the O-ring seal production.

The rough draft of the standard procedure section on O-ring installation is complete. This section describes the proper method of O-ring installation in new or used connectors of systems for marine and other static pressure applications. An abbreviated version of the method is followed by a detailed description and explanation of the method.

Installation as described in this standard procedure encompasses the steps or processes starting from withdrawing the O-rings and connector parts from stock or the shop to releasing the assembled connectors for the next operation of connector test or use. Installation includes withdrawing,

record keeping, inspecting, checking, lubricating, grooving, seating, and testing. Installation is complete when tests of O-ring seating described in the standard procedure give no evidence of improper sealing, and threaded or locking parts are secure but not necessarily tightened. The steps given for the installation should be used as a guide if not referenced by engineering drawings.

The following subsections describe the requirements for reliable O-ring installation:

- O-Ring Specification - The various industrial and military specifications are briefly described as to scope and application.

- O-Ring Package Identification - The proper package marking is described.

- Package Inspection - A description of acceptable O-ring packaging is given.

- Accountability - Proper O-ring accounting procedures are given to record withdrawing from stock and disposition.

- Preparation and Configuration - These subsections describe parts and tool preparation and assembly planning.

- Inspection of Seal Surfaces - Several subsections give procedures for proper inspection of sealing surfaces, seal surface dimensions, and seal surface finish before installation.

- Cleaning Surfaces with Solvents - A description of cleaning seal surfaces and proper solvent use is given.

- Inspection of O-Ring - These subsections describe visual and dimensional inspection of O-rings before installation.

- O-Ring Handling - Proper O-ring handling methods are given to prevent damage.

- Mask Sharp Edges - Methods are given to prevent O-ring damage from passing over sharp edges.

- Lubrication - These subsections give proper procedures for lubrication of sealing surfaces, tools, and O-rings. Selection of the proper lubricant and and criteria for the proper lubricant quantity are described.

· Grooving - Several subsections describe proper procedures for installation of the O-ring into the groove. Limits of O-ring stretching and inspection procedures are given.

· Seating - These subsections describe the operation of final assembly of the seal components. Proper procedures of assembly and test are given.

5.4. PLANS

The first draft of the remaining sections of the standard procedure will be completed during the fourth quarter of FY80, submitted to the three chosen reviewers, and final publication will be initiated.

6. TASK C-3 - CABLES AND CONNECTORS

G.D. Hugus - NRL-USRD
D.E. Glowe - Texas Research Institute, Inc.

6.1. BACKGROUND

The use of cables and connectors is an area of concern for long-term sonar reliability because of a history of failures. Deficiencies can be generally categorized in the four areas of: design of cables and terminations; specification and testing; handling; and repair and maintenance. Specific problems have been identified in a recent failure modes and effects analysis of cables and connectors prepared for NAVSEA by General Dynamics/Electric Boat Division. They concluded that, of all the problem areas, the loss of bond of the molded boot to the connector shell or to the cable sheath is the most probable cause of failure. Cable jacket puncture in handling, at installation, or in service is considered to be the second most probable cause of failure.

6.2. OBJECTIVES

The general objective of the task is to provide improved reliability in the cables, connectors, and related hardware for the outboard elements of sonar transducer systems.

Specific objectives for the FY80 task area are to complete the following:

- Investigate the strength of shielded and unshielded cable to determine reliability and failure modes.

- Investigate the use of cable/connector boot clamps to determine reliability and failure modes.

6.3. PROGRESS

6.3.1. Work is continuing under contract N00173-79-C-0129 with Texas Research Institute, Inc. The final report on the investigation of the strength of shielded and unshielded cable to determine reliability and failure modes has been completed.

The objective of this program was to measure the mechanical properties of shielded and unshielded MIL-C-915/8E cable types and determine the influence of shielding on cable performance and reliability. Ten cable types, five shielded and five unshielded, were mechanically tested to measure tensile strength, flexural abrasion and crush resistance, resistance to creep and performance in hull stuffing tube. Mission profiles for the cable types were developed and maximum stress exposures for the cables identified.

The test results are summarized in Table 6.1 and from the test results and observations the following conclusions can be made:

- Shielding is not required as a strength member in DSS-3 type cable but is required in DSS-2 type cable.

- Unshielded DSS-3 type cable tested does not perform satisfactorily in a hull stuffing tube.

- Shielding is not required for cable crush resistance.

- Construction parameters other than shielding can significantly affect cable performance.

TEST	CABLE TYPE	INITIAL FAILURE MODES	RESULTS
Tensile	Shielded	Partial shield fracture, open conductor	1. Shielded 20 to 30% stronger. 2. Both DSS-2 types do not meet M.P. requirements.* 3. Both DSS-3 types meet M.P. requirements.*
	Unshielded	Open conductor	
Crush	Shielded	Conductor-to-conductor short	1. Shielded 7 to 15% more crush resistance. 2. Both types meet M.P. requirements.*
	Unshielded	Conductor-to-conductor short	
Flexural Abrasion	Shielded	Partial shielded failure, open conductor	1. Both types exceed M.P. requirements.* 2. Shield damage occurs 50% sooner than conductor damage.
	Unshielded	Open conductor	
Creep in Tension	Shielded	No failure	All cables exceed M.P. requirements.*
	Unshielded	No failure	
Performance in Hull Stuffing Tube	Shielded	No failure	1. No leakage observed in all cables. 2. Unacceptable cable slippage measured in unshielded cables.
	Unshielded	Cable movement observed	

* M.P. = mission profiles

Table 6.1. - MIL-C-915/8E Shielded and Unshielded Cable Test Results

6.3.2. Work on the investigation of the use of cable/connector boot clamps to determine reliability and failure modes is in progress. The failure of a test oven used in the accelerated life testing (ALT) of the connectors was described in the preceding quarterly progress report [2]. Testing was stopped and the 64 test connectors were refabricated and have currently completed eight of the ALT cycles [1]. No connector failures have occurred from the ALT except for two attributed to fabrication defects.

6.4. PLANS

The final report on the shielded and unshielded cable strength investigation will be published and distributed during the fourth quarter of FY80. Work on the investigation of cable/connector boot clamps will be completed in the fourth quarter of FY80 and the final report submitted for publication.

7. TASK D-1 - ALTERNATIVE MATERIALS: PLASTICS

D.E. Moore & K. Niemiller - NUSC

7.1. BACKGROUND

Corrosion, cost and acoustic characteristics are parameters that must be considered when selecting a material for the design of a sonar transducer. In the past decade, plastics have decreased in cost and increased in strength to the point that they are in strong competition with metals for specific applications. Plastics could be used as a design material for sonar transducers in order to lower costs and lengthen service life if they can withstand the ocean environment. An additional advantage is that plastics generally are electrically nonconductive and acoustically transparent.

Specifically, the injection molded thermoplastics are the best materials for consideration as an alternative assembly material since they can be molded to close dimensional tolerances and in many configurations. Metals and electronic connectors can be molded directly into the plastics thus reducing the number of separable parts and insuring in-service reliability.

Naval facilities equipped with the proper molding equipment can fabricate replacement parts for sonar transducers when parts are not in stock or readily available. This would be extremely helpful when emergency repair is necessary and the time for normal procurement procedures is not available. In the event that a shortage of material should occur, thermoplastics can be easily recycled.

Presently there is no general long-term ocean immersion data available for thermoplastics. It would take many years of testing and analysis to determine the long-term life expectancy, but there is an immediate need for information. The only approach for determining this information in a reduced time period is to perform accelerated life testing (ALT), but this must be used with caution. When this method is used, it is always recommended that comparison be made to parts which have been exposed to the actual environment in question.

7.2. OBJECTIVE

Evaluate the ability of plastics to withstand an ocean environment and the reliability of the ALT method for use in determining long-term material life expectancy.

The approach to the objective is as follows:

- Perform a two-year equivalent ALT on eight types of glass-filled thermoplastic materials immersed continuously in substitute ocean water (ASTM D-1141).

- Immerse eight types of thermoplastics in an ocean environment, with an approximate constant temperature, for two years.

- Evaluate test specimens of both aging environments for changes in major material properties.

- Compare the data for the two environments to determine both the aging characteristics and the validity of a 10-20 year equivalent ALT for glass-filled thermoplastics.

If the results of degradation for the ocean test agree reasonably well with the laboratory ALT, it will be possible to accurately determine the extended life expectancy of plastics. In addition, it will be possible to classify materials according to limitation of properties.

7.4. PROGRESS

Some delays have been caused during this quarter by the late delivery of plastics by the supplier. All samples have now been received (more than two months late). Molding of specimens for the various tests will be completed within the first two weeks of the fourth quarter FY80. Exposure of the samples to the ocean testing is scheduled to begin on 31 July 1980 at the Naval Research Laboratory's Corrosion Testing Laboratory in Key West, FL. Dr. Bogar, of that laboratory, will remove samples from the test site and ship them to NWSC for testing according to the previously discussed schedule. Laboratory ALT of identical samples will begin during August 1980.

The test specimens will be subjected to material property tests at varying time intervals including:

- Tensile Strength (ASTM D-638)
- Shear Strength (ASTM D-732)
- Water Absorption (direct measurement; ΔW)
- Volumetric Change (direct measurement; ΔW)
- Sound Speed (time of flight velocimeter at USRD)

These material properties were selected because these are the first-line preventive measures of transducer failures. For instance, if a protective casing was made of a glass-filled plastic, then water absorption must definitely be considered since any permeation for a given period would damage the electronic circuitry. An expansion or shrinkage (volumetric change) could possibly change the response of the resonator assembly. A drastic change in shear strength might cause a bolt hole for mounting to crack and the transducer to dislocate from the mounting bracket. Sound speed must definitely be analyzed in the event that the plastic is used as an acoustic window. Tensile strength, though not normally considered when designing casings, can be used to generate Young's Modulus and can also be used as a comparison for material changes or selection of a material. Tensile strength is, more often than not, used as an engineering tool.

Recently, recommendations were made for evaluating additional parameters of creep and degradation when the material is fatigued or stressed. These are important considerations but time and funds make it impossible to perform this analysis for this project time frame (FY80)· these topics will be investigated in FY81.

One property evaluation that will be performed during this cycle of tests, in addition to the existing proceudre, is the effect of seawater on machined plastics. This will be accomplished by milling the surfaces of molded test specimens of selected materials. The parts will be evaluated according to the aforementioned procedures but tested at lesser intervals. This will provide some indication if machining does drastically affect strength and the resistance to moisture absorption.

Mr. Dale E. Moore, the former principal investigator of this task, has resigned from government service. The new principal investigator is Mr. K. Niemiller of NWSC.

7.4. PLANS

- Complete test specimen fabrication.
- Test plastics for baseline data.
- Install parts at ocean test site (31 July 1980).
- Begin ALT in laboratory.
- Perform first parts evaluation.
- Evaluate the materials in detail to determine trends in degradation.

8. TASK D-2 - MATERIALS EVALUATION

C. LeFlare - NUSC
C.M. Thompson - NRL-USRD

8.1. BACKGROUND

Pressure release materials are used to mechanically and/or acoustically isolate some components of sonar transducers to improve overall acoustic performance. Normally the pressure release materials must operate effectively under bias stress anywhere from 0.3 MPa (50 psi) to 20 MPa (3 kpsi) over a discrete temperature range, e.g., 5 to 40°C. To predict performance it is essential to know the properties of the materials under the imposed constraints. Previous measurement methods for determining the properties of some pressure release materials, such as Sonite (an asbestos - glass fiber composite), onion-skin paper, syntactic foams, Hytrel (a thermoplastic polyester elastomer), etc., have given relative results with a hydraulic press or bulk effects with an impedance tube. There is a strong need to correlate existing measurement data and to establish a standard measurement system to be used by the Navy for incorporation into specifications and/or acceptance tests on pressure release materials.

An additional problem is that pressure release materials absorb the transducer fill-fluids. This process increases the acoustic impedance of the pressure release material and thus reduces the effectiveness of its acoustic insulation. Degradations of from 3 dB in 3 years to 6 dB in 10 years have been reported in transducers in the field, and attributed to changes in the pressure release material.

There are thus two phases to this task: the material characterization phase and the fluid absorption phase.

8.2. OBJECTIVES

The objectives of this task are:

- To initiate and evaluate a standard static and dynamic measurement system to determine the properties of pressure release materials over the ranges of stress from 50 psi to 3 kpsi and at temperatures from 5 to 40°C.

- To measure and evaluate candidate pressure release materials, such as Sonite, onion-skin. corprene. etc.

- To quantify the changes in acoustic properties of cork-rubber composites as they absorb transducer fill-fluids.

- To test a transducer element for changes in sensitivity as a function of castor oil content of its pressure release material.

- To develop a method that will predict changes in the acoustic properties of cork-rubber composites with time and, in turn, predict changes in transducer directivity and sensitivity.

- To identify the specific problems with DC-100 which may eventually lead to its replacement with a more suitable material.

8.3. PROGRESS

8.3.1. The last four objectives above have been accomplished and have been reported in previous STRIP reports. A master's thesis from the Florida Institute of Technology entitled "The Acoustic Decoupling Properties of Cork-Rubber Composite Materials as a Function of Transducer Fill-Fluid Absorption," by L.E. Horsley, has been published. A comprehensive final report is being edited and an abbreviated version is being prepared for submission to the open literature.

8.3.2. A dynamic measurement system consisting of a double mass-loaded longitudinal resonator with a detachable sample holder on one end has been constructed and can be freely suspended. The sample and loading mass are connected in tandem and bolted into the head mass with a separate stress rod to control the static stress level on the sample. The low-frequency resonance and quality factor associated with the unknown sample and loading mass are measured as the ceramic stack is driven electrically with a sinusoidal voltage. A math model has been developed to determine the sample properties from the measured parameters.

Initial static measurement on samples of Hytrel, a thermoplastic polyester elastomer contemplated for use in the TR-155 transducer design. indicated the need to define initial conditions (i.e., stress levels and stress cycles needed for stabilization) on materials before dynamic testing. To determine the proper sequence for initial stress conditions on Hytrel, four samples, roughly 3.5-in. outside diameter by 0.75-in. inside diameter by 0.95-in. thick, were machined from a DuPont compression molded slab of hardness (durometer) grade 55D.

The gross dimensions of the test samples were not considered critical (±0.005 in. on all dimensions). However, precision machining (±0.001 in. on all surfaces and the same on perpendicular and parallel alignment) was required to insure proper loading by the platens of the hydraulic press and precise measurement of the displacement under compression (±2 mils maximum with vernier calipers). The total thickness displacement to a stress level of 2.6 kpsi was 70 mils.

The first virgin sample was stressed to a level of 2.6 kpsi in steps of 0.54 kpsi (data points were more closely grouped after the first cycle). A one-minute hold was maintained at each stress level (creep in the sample was noticed at the higher stress levels). The stress versus strain curve was slightly nonlinear at the higher stress levels.

The initial low level estimate of the static longitudinal modulus was 50.9 kpsi whereas the high level estimate (from 0 psi to a stress level of 2.6 kpsi) was 35.4 kpsi. Continued cycling increased both modulus values slightly, approximately 8%, up to the fifth cycle. An estimate was made of the dynamic modulus about the bias stress level of 2.6 kpsi by taking the slope of the static curve at that point, obtaining a value of 21.7 kpsi. This value is roughly 60% of the static value of 35.4 kpsi quoted above.

The outside radius was also monitored as the load was applied to the sample. The transverse modulus to maximum stress on the first cycle was estimated to be 79.4 kpsi. Comparison of the longitudinal and transverse moduli gives a tentative value for Poisson's ratio of 0.44.

The first precise sample of Hytrel will be further cycled to determine long-term effects. Measurements will be repeated on a second sample to confirm initial results and to establish an acceptable stress cycling procedure for Hytrel. The remaining samples will simply be stress cycled according to the established procedure and then all samples will be measured dynamically using the electromechanical driver transducer assembly and the results will be compared. These same samples will ultimately be tested using the dynamic impulse technique advocated by Raytheon.

A smaller sample of the same material, about 2.0 in. in diameter (solid puck), has been machined with the same tolerances and will be used for determining density versus stress variations and to get a better estimate of Poisson's ratio, i.e., no ambiguity due to the inside diameter variations as on the other samples.

Anticipated work under this task in FY81 includes measurement of the complex sound speed of materials under specified constraints intended to simulate the conditions of actual transducer configurations. A technique utilizing spectrum analysis of the impulse response initiated by the Submarine Signal Division of the Raytheon Company will be used. Results have already been obtained on a 3-in. long by 3-in. diameter stack of fiberglass rings. The sample is contained between two masses and prestressed with a stress rod. Math models were used to estimate the complex sound speed from data taken when the sample was excited by a cw signal and by an impulse force. The resonance frequency and mechanical quality factor were evaluated for both test conditions and the resulting complex sound speeds, c^*, were obtained:

- Electromechanical Driver Transducer (cw) — $c^* = (2550 + j16.2)$ m/sec
- Impulse Drive plus Spectrum Analysis — $c^* = (2436 + j15.2)$ m/sec

The difference between the two methods amounts to about 4% for the real part of the complex sound speed. This is a reasonable difference for a stiff fiberglass material but the difference might increase for softer type pressure release materials. This latter aspect must be investigated.

8.4. PLANS

- Other samples will be stress-cycled with a hydraulic press to see if a stability, or lack of creep, can be obtained.
- Measure static and dynamic properties of pressure release material at ambient temperatures.
- Collect information and prepare report on the measurement of properties of pressure release materials.

9. TASK E-1 - STANDARDIZED TEST PROCEDURES

J. Wong & D. Huckle - NOSC

9.1. BACKGROUND

It is at present not possible to subject a transducer specimen to a series of environmental stresses over a short time period and prove, if it passes certain operating parameter tests, that the specimen is a reliable transducer with a certain minimum expected life in fleet use. Of course, if we could simply use a set of transducers for the desired fleet life, we could check the failure rates against acceptable replacement or repair rates; but the approach here is to accelerate the environmental stress actions and thereby subject the transducer specimen to seven years of life cycle stresses in a few weeks or months.

9.2. OBJECTIVES

The objective of this task is to develop a set of standardized procedures based on environmental stress requirements to accelerate the aging of transducers.

9.3. PROGRESS

9.3.1. First Year Equivalent of Composite Unit Accelerated Life Testing (CUALT) on New TR-316 (First Article) Projectors

Three new TR-316 first article projectors (serials A1, A2, and A3) were manufactured by Ametek/Straza incorporating the modifications [2] recommended after the extensive tests in uncovering the current runaway problem during the high drive test on the prototype TR-215 projectors. Ametek/Straza exposed these three units to 168 hours (seven days) of high drive with frequency sweep at 126 V rms input in approximately 3 m (10 ft) of water during November 1979.

These three projectors were released to NOSC in November 1979. Low level (10 V rms) baseline acoustic performance was measured at TRANSDEC in December 1979 and January 1980 and found to be within specifications. It was decided to perform a short duration (approximately one hour) high drive test on the wide-beam sections of these units prior to submitting them to the CUALT plan. To facilitate impedance monitoring, a single frequency (at the lowest operating band) at 116 V rms was used. Projectors A2 and A3 were lowered to a water depth of 10.5 m (34 ft), the maximum depth at TRANSDEC. The input impedance magnitudes of the wide-beam sections of projector A3 increased from approximately 50 ohms at the start of the high drive to stabilized values of 65 to 70 ohms after 20 minutes. However, the stabilized impedances are still approximately 35 ohms lower than the low level baseline values. Similar trends were found for projectors A2 and A1. It was conjectured that cavitations may be present to alter the projector input impedance. To avoid cavitation, the above test was repeated with the projectors inserted in a pressure vessel with a pressure of approximately 483 kPa (70 psi). With the projectors in the

pressure vessel the impedances at the start of the high drive agree with the low level baseline values of the corresponding wide-beam sections. After approximately ten minutes the impedances increased to stabilized values of only 5 to 10 ohms above the starting values. Subsequent dissembly of a wide-beam section, the PD down beam of A1, to investigate the cause of a failure revealed fine cavitation pits on the inside surface of the rubber window opposite the resonator elements. These measurements indicate that cavitation was present in the wide-beam sections at the water depth of 10.5 m (34 ft).

Due to the current runaway problem in the PD up- and PD down-beam sections (the wide-beam sections) induced by the high drive in the TR-215 prototype projectors, it was decided to perform the high drive stress exposure as the first sequence instead of the sixth sequence as indicated in the CUALT plan [2]. After it has been confirmed that the high drive problem has been corrected in the revised TR-316 projectors, the stress exposure sequence from the CUALT plan will again be followed. To expedite the CUALT plan it was also decided to perform the high drive stress without using the pressure vessel even though there was a possibility that cavitation may occur in the wide-beam sections.

Projectors A2 and A3 were selected for the CUALT and projector A1 was reserved as a reference for aging comparison. The two projectors were mounted side by side on a platform in the horizontal position and lowered to a water depth of 10 m (33 ft) near the bottom of the TRANSDEC pool. A computer-controlled frequency synthesizer was used to generate the two-second sweep frequency drive at 123 ±5 V rms. Within the two-second period, 50 discrete frequencies are generated to cover the operating frequency band of 8000 Hz (approximately 163 Hz increments). These 50 frequencies, from the lower to the upper band limits, were swept every two seconds. The switching time between any two consecutive frequencies was approximately one millisecond; thus providing continuous two-second linear step frequency sweeps.

All six beams of the two projectors were driven simultaneously using the Instruments Inc. Model LDV2-5 Kilowatt Amplifier. The input voltage, input current and input impedance (magnitude and phase angle) of each of the six beams were measured at eight selected frequencies out of the 50 generated in the operating frequency band. These measurements at the eight frequencies for each beam were completed in less than two seconds with the data stored in the HP9825A calculator. During the next successive two-second period, measurements for the next beam were made. Hence, in a period of twelve seconds, impedance measurements of eight difference frequencies in the operating band for each of the six beam sections in the two projectors were performed and stored. Finally, the stored data at each frequency were printed out giving the frequency, input voltage, input current, impedance magnitude, impedance phase angle and time of day. Data taking and printout can be programmed to repeat from the minimum interval of every two minutes to any other desired time interval.

During the initial checkout of the high drive system it was noticed that the impedance of the up-beam section of projector A2 was deteriorating, lowering in values at the lower frequencies. Air bubbles were suspected in up-beam section. The projectors were raised out of the water and the rubber windows of all three sections were tapped for evidence of air bubbles. The tappings indicated that both the up-beam and the narrow-beam sections had air. This was confirmed by moving an accelerometer probe across the rubber window surfaces to detect the signal when all three beams were driven with a 10 V rms signal at the mid-band frequency. The probe signal decreased below the background noise level when the probe was above the suspected air bubble. During the probe test, the projector was first in a horizontal position. When the projector was tipped on its side, the air bubbles moved away from the rubber window and the probe signals became as strong as the beam section that had no air bubbles.

Project A2 was removed from the CUALT and replaced with projector A1. A2 will be used as a reference for aging comparison.

Prior to the start of the high drive (123 ±5 V rms) a low level drive (10 V rms) was applied to the two projectors (A1 and A3), one beam section at a time, to obtain reference impedance data for each beam. These reference impedance data, when compared to the low level baseline impedance data, indicate the condition of each beam immediately prior to the initiation of the high drive test.

The high drive test began at noon on 27 March 1980 and was uneventful for the first continuous 53½ hours. However, within the next five-minute interval, the time interval between impedance readouts of each beam, the impedance of the PD down-beam section of projector A1 went inductive. The inductive impedance indicates a possible short circuit across the five paralleled resonator elements in this beam section. There was no excessive current readouts before or after the beam section went inductive. High drive was not interrupted to disconnect the shorted beam section since the current was limited by the tuning inductor in series with the five paralleled resonator elements. Due to TRANSDEC's time schedule, only 116 hours of continuous high drive was completed. An additional 53 hours of continuous high drive was completed during 11-13 April 1980 for a required total of at least 168 hours to simulate one year equivalent of high drive stress. The PD down-beam section of projector A1 was not driven during the last 53 hours of high drive. A low level impedance check of each beam of projectors A1 and A3 20 hours after the high drive indicate that all five beam sections appeared to be satisfactory (down-beam section of A1 was still inductive).

The down-beam section of projector A2 was disassembled to investigate the cause of the suspected electrical short across the five paralleled resonators occurred during the high drive. The following were observed during the disassembly:

- Metal chips and filings were found in the drained fill-fluid. After the fill fluid was completely drained more metal chips and filings were found deposited on the anodized aluminum retained block, the pressure release pad, surfaces of the resonators and the internal surfaces of the down-beam section cavity. One side and the top edges of this beam section cavity appeared to have been filed, probably to fit the aluminum retainer block into the cavity. Apparently not all of the filings had been removed. It is not known how the metal chips (they appeared to be stainless steel chips - some approximately 2.5x0.5 mm in size) got into the cavity. One possibility was that these metal chips were burrs or residual chips that had not been removed after machining of the projector case.

- Black, hard carbon-like deposites were noticed on the surfaces of the two ceramic rings between the aluminum head mass and the nodal ring of two resonators, serials 039 and 090. The carbon-like deposits were particularly heavy on the ceramic ring adjacent to the nodal ring on resonator serial 039. Measurements of the two leads across this ceramic stack indicated a dc resistance of 185 ohms. It was this resistance that effectively shorted out the beam section. The lighter carbon deposits on resonator serial 090 measured 884 k ohms, indicating an early stage of carbon buildup. It is not known whether the presence of the metal filings and chips or other contaminants on the ceramic surfaces caused arcing and the resulting carbon deposits; but certainly the metal filings and chips are strong suspects.

- All five of the resonators' aluminum alloy head masses had small crack-like lines on the radiating faces. Actually, these were not cracks but were etch patterns caused by cavitation. (Similar etch patterns were noticed on the earlier TR-215 resonators after the high drive exposure and Ametek/Straza had reported that these etch patterns were caused by cavitation.) Small clusters of pit marks were visible on the inside surface of the rubber window opposite the resonator head masses which confirmed that the resonators had been driven to cavitation under the high drive condition. Ametek/Straza was notified of the failure and the metal chips and filings found in the down-beam section cavity.

Five new resonators were obtained from Ametek/Straza as replacements for the failed down-beam section. After the down-beam section was

reassembled and low level acoustic performance checks indicated that it met specifications, projector A1 was returned to the ALT five weeks behind schedule.

Projector A3 had 250 cycles of pressure cycling with 32 hours of 600 psi dwell, followed by 40 hours of 60°C fresh water soak, 3 cycles of thermal shock, -54°C to 0°C, and the repeat pressure cycling and dwells in that order. Due to the delay caused by the failure of the down-beam section and the effort to economize the CUALT by simultaneous application of applicable stress exposures to both the TR-316 and DT-605 transducers, projector A1 did not have the 60°C fresh water soak, thermal shock or the repeat pressure cycling exposures (exposures 2, 4, and 5). It was, however, exposed to 250 cycles of pressure cycling and dwells (exposure 3).

Dry heat (75°C) and ultraviolet (UV) exposure was initiated on 6 June 1980 for projectors A1 and A3. Within the time period of 1-68 hours (during the weekend) the up-beam section rubber window of projector A1 ruptured with some loss of fill-fluid. The rupture of the rubber occurred along one edge of the window opening of the stainless steel coverplate, commonly referred as the ice shield. The expansion of the fill-fluid causes the rubber window to bulge and can produce shearing stresses on the rubber along the window opening. An in-depth analyses of the rupture will be made.

It sould be noted that the dry heat exposure air temperature of 75°C is 4°C above the maximum nonoperating temperature of 71°C (160°F) specified in the CIPS (10 June 1977) for both the TR-316 and the DT-605 transducers. Therefore, the remaining and future dry heat and UV exposure air temperature will be lowered to 71°C.

Serial No.	Stress Exposure	Test Dates Started	Test Dates Completed	Comments
A1, A3	No. 6 High-Drive	3-27-80	4-14-80	PD down beam section of A1 developed a short-circuit across the 5 paralleled resonators. Probable cause is metal chips and filings left in beam section cavity at production platn. No changes in durometer values of rubber windows compared to pre-CUALT Shore Hardness No. 55 for A1, No. 50-55 for A3.
A3	Nos. 3, 2, & 4 Pressure Cycling, 60°C Fresh Water Soak & Thermal Shock	4-22-80	5-15-80	Shore Hardness No. 55-60 for A3 (slight increase in durometer values in rubber window).
A1, A3	No. 5 Pressure Cycling	5-27-80	5-29-80	Shore Hardness No. 55 for A1, NO. 55-60 for A3 (no changes in durometer values in the rubber window).
A1, A3	No. 1 Dry Heat & UV	6-6-80		Rubber window of up beam section of A1 ruptured along one edge of stainless steel ice shield window opening within first 68 hours of 75°C dry heat & UV exposure. A1 was removed from test chamber. Continued with A3 but with reduced chamber air temperature of 71°C.

Table 9.1. - Summary of TR-316 (First Article) Projectors First Year Equivalent of CUALT

9.3.2. DT-605 First Article Hydrophones

The third year equivalent of CUALT for the two Hazeltine Corporation DT-605 first article hydrophones, serials A1 and A5, was completed in June 1980. No problems were encountered during the CUALT. A cursory inspection of the acoustic data after the third year equivalent of CUALT indicated that both A1 and A5 hydrophones are still within specifications.

9.3.3. CUALT Documentation

A report documenting CUALT procedures as applied to sonar transducers has been published and distributed (NUSC Technical Report 516).

9.4. PLANS

- Continue with CUALT on the two Hazeltine Corporation DT-605 hydrophones to complete as much as possible of the seven year equivalent CUALT.
- Continue with CUALT on the Ametek/Straza TR-316 projectors and complete as much as possible of the seven year equivalent CUALT.
- Revise the dry heat and UV stress exposure air temperature from 75°C to 71°C and increase exposure time in future CUALT plan. Future high drive exposure will be performed with the projectors in a wet pressure chamber to simulate sufficient water depth to avoid cavitation.
- Begin development of CUALT procedure for the SQS-56 transducers.

10. TASK E-2 - ACCELERATED LIFE TEST VERIFICATION

T. T. Moore, K. McClure, & D. Steel - NAVWPNSUPPCEN

10.1. BACKGROUND

Until recently sonar transducers that were used in the fleet were fabricated and put into operation with limited life testing. Some units performed quite well throughout the expected service life while others exhibited an early high failure rate. Costs of transducers have increased dramatically and the life requirements have been increased to fit new overhaul schedules. These and other factors have mandated verifying the reliability of units for the entire service life. In order to determine the reliability of transducers for a given time of service, it was determined that the approach of Composite Unit Accelerated Life Tests (CUALT) should be used. This method not only investigates the physical degradation of the materials used in the transducer assembly, but also the susceptibility to mechanical or electrical failures. Just as Accelerated Life Tests (ALT) for materials need to be verified by using specimens that have been exposed for the full duration to the environment being evaluated, this must also be done for CUALT.

Approximately 1½ years ago a complete array of 48 DT-168B hydrophones was removed from the USS Stonewall Jackson (SSBN-634) and retained intact for post-service evaluation at NUSC New London. This array of hydrophones had undergone extensive evaluation at NUSC before being installed in the SSBN-634. It was decided that these hydrophones could be used to verify the acceptability of using CUALT for hydrophones.

The DT-168B is the passive sensor for the AN/BQR-2B sonar system. This set of 48 hydrophones was fabricated by NAVWPNSUPPCEN in Crane, IN, in 1972. Three sets of five air-backed cylindrical ceramics made of lead-zirconate-titanate (PZT-5A) wired in parallel series are the main internal electrical components. The ceramics are protected by a steel cage that is covered by a butyl rubber acoustic window. The elements are isolated from the cage by rubber grommets. Shielded DSS-3 cable 125-ft long is used to connect each hydrophone to the system.

By fabricating ten hydrophone units identical to those in the array and performing an established CUALT on these units it will be possible to compare the degradation of these units to the information retrieved from the post-service hydrophones.

10.2. OBJECTIVE

To verify the accuracy of the CUALT method by comparing results with a known real-time life test.

10.3. PROGRESS

In an attempt to generate a mission profile for the DT-168B CUALT the Applied Physics Laboratory at Johns Hopkins University was contacted in order to obtain environmental information from the CNC Data Log of SSBN-634. The information that is available is keel depth and salinity, and the

duration of retention is only 36 months. Therefore, it has been determined that it will be necessary to use the hypothetical mission profile developed by the Texas Research Institute for SSBNs.

The DT-168B hydrophones that will replicate the units built in 1972 are being fabricated and are nearing completion. These units will be completed in time to be ready for implementation of the CUALT in July 1980.

10.4. PLANS

- Complete test and evaluation of post-service hydrophones (2nd effort).
- Develop a CUALT procedure (mid-July 1980).
- Complete fabrication of the ten new hydrophones (end of July 1980).
- Test and evaluate the hydrophones.
- Begin ALT (mid-August 1980).
- Test and evaluate the hydrophones for degradation of physical and electrical properties.
- Compare the test data with that of post-service hydrophones for determination of CUALT reliability or effectiveness.

11. TASK F-1 - ENGINEERING ANALYSIS: FAILURE MODES DUE TO WATER

D. Barrett & P.F. Cassidy - Texas Research Institute, Inc.

11.1. BACKGROUND

Previous studies have developed some of the techniques of calculating the rate of water ingress into a transducer case, but more or less severe assumptions have had to be made for these calculations to date. In addition to the assumptions about the rate of water ingress, little work has been done on the effects of the ingressed water. The various failure mechanisms that can be triggered by the presence of water are not well understood and are not quantized.

11.2. OBJECTIVES

The purpose of this task is to investigate the effects of water permeating into a transducer; specifically, to determine the effects on reliability and performance (not related to corona and arcing). The immediate objectives are to determine the composition of the permeant and to measure parameter variations in a transducer as a function of humidity.

11.3. PROGRESS

The work is being done in phases which are designed to determine what happens to water once it gets into a transducer and how it affects the lifetime of the transducer. The first phase will determine the composition of the permeant - the quantity and type of dissolved solids which come through with water, whether they are from seawater or contaminants from the elastomer. The second phase will be to test the effect of water on the lifetime functions of a transducer.

For Phase I, several pieces of Neoprene WRT were exposed to boiling, deionized water in a round-bottomed flask for eight days. The conductivity of the water decreased from 94,000 ohm-cm to 20.8 ohm-cm. The rubber samples which had an original weight of 94.9 g increased in weight to 145.2 g during the process of extraction by water. These samples were then allowed to dry, first under ambient conditions and then in a desiccator. This is being done to determine the total weight loss by extraction. To date, however, the samples still have a weight greater than their original weight, indicating incomplete drying. The surface of the samples show a white crusty deposit an indication that components of the rubber are carried out with water diffusion (or by the heating).

The organic content of the water extract was determined qualitatively by gas chromatography. As a standard, a sample of water which contained 0.1% acetone was injected and the response of the gas chromatograph was determined. The unknown, that is the water extract from the rubber sample, was injected and the response of the gas chromatograph was four times that of the standard. This does not mean, of course, that the organics were there at a level of 0.4%, but the response was significant and further organic analysis is required.

Because the above limited test showed some response, a more rigorous analysis, gas chromatography/mass spectrometry (gc/ms), was conducted on a chloroform extract of the water extract. Several species were found with ion masses of 57, 59, 87, 89, 101, and 103. However, the computer search process did not uncover the identity of these materials.

In order to determine qualitatively and quantitatively the inorganic content, the water extract and a white crystalline solid which precipitated from this extract were analyzed by emission spectroscopy. The water extract was evaporated and ashed. The weight of the remaining residue was 0.105% that of the original sample. The ash gave the following results:

ELEMENT	% IN ASH	% IN WATER EXTRACT
Mg	18	0.019
Ni	6	0.006
Na	5	0.005
Ca	3	0.003
Si	3	0.003

The white solid had 73.21% ash and gave:

ELEMENT	% IN ASH	% IN WHITE SOLID
Si	23	16.8
Mg	14	10.2
B	0.4	0.3
Fe	0.2	0.15

It appears that a magnesium salt was extracted along with a portion of the clay (silicate) filler as the major components. The total weight of material extracted from the rubber is estimated to be less than 1 g.

A TR-208A element which had been previously dissected was studied for possible methods to enter the housing and to instrument it. A plan was devised and implemented for one TR-208A element with the following results:

- A technique has been developed which will allow the determination of relative humidity by gas chromatography using electron capture detectors.

- A small hole was drilled to allow entry to the cavity to withdraw a gas sample for humidity determinations. On this element (fresh from the TRF at MINSY) there was 56% relative humidity in the interior.

- The element was entered by cutting holes large enough to allow rewiring to take place on the stack. This hole was fitted with a short piece of PVC pipe which

was sealed so that the element could be submerged without danger of water entry. Two wire leads and two gas purge tubes were fed through the pipe.

- The element was thoroughly purged with dry gas and the output gas was passed through Drierite. The total water content of the element will be determined.

- The internal resistance and impedance were measured in air as a function of frequency.

- The element was sent to NRL-USRD for baseline sensitivity determination and returned to TRI for further experimentation.

11.4. PLANS

- The extraction experiment will be rerun at a lower temperature (75°C) to verify the validity of the earlier high temperature (100°C) process.

- The rubber composition will be sought from the supplier.

- A permeation experiment will be conducted to determine whether the results are similar to water extraction.

- A literature search will be conducted on composition of rubber permeants.

- Other TR-208A elements will be instrumented, calibrated, and tested at stepwise increasing water content.

- An accelerated test will be performed on a 208A element containing a moderate level of moisture.

- A report will be prepared on the rate of water permeation into an actual transducer case.

12. TASK F-2 - TEST AND EVALUATION: SHOCK HARDENED PRESSURE RELEASE

C.R. Wilson - Westinghouse

12.1. BACKGROUND

A study recently completed by Westinghouse addressed the use of polyimide and glass-loaded polyester materials as a pressure release mechanism in the TR-155F transducer. Transducers using these pressure release materials in place of the "standard" Belleville springs were subjected to extraneous noise tests, acoustic tests, and explosive shock tests. While the noise and acoustic test results were encouraging, the pressure release configurations were not intended to withstand the rigors of explosive shock.

12.2. OBJECTIVES

The objectives of this task are to develop, test, and evaluate the effectiveness of polyimide and polyester-elastomer-glass as a shock hardened pressure release material.

12.3. PROGRESS

Six TR-155F transducers have been retrofitted with two types of pressure release materials; three with a disc of 20% glass-loaded polyester and three with a polyimide ring. After correction of a "bottoming out" problem with two of the polyimide retrofitted transducers, all six transducers were subjected to acoustic tests at USRD. With the exception of the low-frequency free-field voltage sensitivity of the polyimide retrofitted transducers, all units were found to be within specification over the frequency, temperature, and pressure ranges of interest.

Eight additional transducers, four of each type, have undergone extraneous noise tests at NWSC in Crane, IN. To date, three glass-loaded polyester retrofitted transducers have passed while one failed due to a faulty cable; one polyimide retrofitted transducer has passed while three have failed. A new transducer was retrofitted with the glass-loaded polyester pressure release to replace the one with a failed cable. Investigation of the three failed polyimide retrofitted units indicated that a likely source of noise was in the bonded joint between the polyimide and steel snubber-rings. The three polyimide retrofitted units have been rebuilt using thicker polyimide rings which are compliantly attached to the steel snubber-rings. These four replacement units are currently being tested at NWSC.

As the failed units were disassembled, the "set" (compression in the axial direction) taken by the pressure release material was measured. The glass-loaded ployester exhibited a "set" of less than 0.51 mm (.002 in.) while the thin walled polyimide ring measured .508 mm (.020 in.).

One unit of each type has been shipped to Hunter's Point, CA, for explosive shock tests during the month of July.

12.4. PLANS

Extraneous noise tests of the four resubmitted transducers will be completed in the near future. Explosive shock tests are scheduled for completion in mid-July 1980. The analysis of results and final report will be completed during August 1980.

13. TASK F-3 - RELIABILITY AND LIFE PREDICTION SPECIFICATION

R.L. Smith & D.D. Barrett - Texas Research Institute

13.1. BACKGROUND

The reliability and life requirements for wet end sonar equipment must have better definition; present reliability prediction methods do not adequately account for redundancy, and current life prediction methods are subjective. Improvements in reliability and life definition and prediction are needed for STRIP objectives to be met, for example MTBF does not uniquely specify the reliability in the time frame of interest which is the first few years of service. Other factors, such as the definition of failure, and the use of redundancy in the design, dominate the reliability versus time relationships. Specifying life in years does not handle the problem of shelf life nor does it uniquely specify wearout reliability.

Reliability is a very strong statistical concept based on the behavior of a group of nominally identical items. Reliability itself is a distributed quantity (i.e., best represented by a normalized distribution or probability density function). The parameters appearing in reliability models are also distributed. Inferences relating to all such quantities are based on limited sets of observations which yield only estimates of the parameters of interest. However, the methods of statistical inference allow us to make the most definitive statements possible.

The present approach used by the Navy for wet end sonar equipment procurements is to specify numerical reliability and life requirements in the Critical Item Procurement Specification (CIPS) and to have the contractor achieve these requirements through a reliability program described in attachment 2 to the contract. Unfortunately, for the reasons given above, a contractor can fulfill all the requirements as currently stated and still deliver unreliable, short-lived hardware.

13.2. OBJECTIVES

There are two major wet end sonar reliability objectives: providing the analytical basis for improved hardware reliability, and facilitating hardware improvement by developing more satisfactory procurement specifications. Intermediate subtask objectives in support of the above are:

- Learn how to analyze the superposition of random and wearout reliabilities.
- Learn how to extract wearout failure mechanisms and random failure hazards from an FMEA.
- Learn how to put a time scale on the wearout failure mechanisms vis-a-vis activation energies, stress amplitudes and cycling, etc.
- Learn how to do a life prediction.

- Improve present (random) reliability prediction methods by correct analysis of redundancy and definitions of failure.

- Learn how to superimpose the results of last two subtasks above.

- Learn how to handle subjective information (Bayesian reliability).

- Figure out how the contractor can achieve the predicted overall reliability (random and life) with appropriate contactor-managed reliability achievement programs (critical parts management, piece-part testing, compatibility studies, QC inspection, design reviews, etc).

- Learn how to tell a contractor how to do all of the above.

13.3. PROGRESS

This is a separate analytical reliability STRIP task initiated in FY80. Work is being performed by Texas Research Institute, Inc., under contract N00024-79-C-6232. The approach for FY80 is to complete work on intermediate objectives 1 and 5. A fairly comprehensive document fulfilling objectives 1 and 5 is in preparation. This report is being generated early in the overall program because its focus is largely to expose well developed ideas in the fields of reliability theory and probabilistic design which should properly influence the shaping of future reliability studies.

Work during this reporting period has included the development of an illustrative corrosion wearout model suggesting log normally distributed times to failure. This is an appealing result since a variety of corrosion and fatigue situations are known, experimentally, to exhibit this characteristic. Texas Research Institute's corrosion work to date has dealt with modeling the strength loss of a load bearing member such as a threaded fastener. This work is to be considered preliminary to a study of the perforation of a transducer housing due to corrosion. Housing perforation and leakage is considered to be the dominant wearout process associated with this structure.

An important aspect of corrosion modeling is the correct manipulation of distributed quantities. Random variable transformations and distribution syntheses have also been studied in support of estimating reliability parameters and developing confidence statements in other reliability settings. The distribution properties so fundamental to the probabilistic design field are completely overlooked in handbook prediction. The handbook approach is said to be deterministic; here the term *deterministic* does not mean correct or fully characterized, it simply means all dispersion effects are ignored.

13.4. PLANS

Plans for the remainder of FY80 include near-term completion of the reliability review report. This will be followed by a separate document addressing the expected quality of the handbook prediction method. The latter report will be an attempt to characterize the dispersion effects normally overlooked in handbook modeling. An open literature corrosion modeling offering is also a possible outgrowth of present work.

It is quite likely that distributional reliability inputs can be most satisfactorily defined via the direct use of curve fitting methods.

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